



## The Deployed Warfighter Protection (DWFP) Research Program: Developing New Public Health Pesticides, Application Technologies, and Repellent Systems

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J. Integ. Pest Mngmt. 4(2): 2013; DOI: <http://dx.doi.org/10.1603/IPM11024>

**ABSTRACT.** The Research Program for Deployed Warfighter Protection (DWFP) against disease-carrying insects is an initiative by the United States Department of Defense to develop, validate and use novel materials and technologies to protect deployed military personnel from vector-borne diseases, especially those transmitted by mosquitoes and sand flies. Launched in 2004 and administered by the U.S. Armed Forces Pest Management Board, the program is funded at US\$5 million annually. The DWFP research portfolio is concentrated in three areas: novel insecticide chemistries/formulations, application technologies, and personal protective measures. The program supports research by the U.S. Department of Agriculture, Agricultural Research Service National Program for Veterinary, Medical and Urban Entomology, plus a competitive grants process open to non-USDA scientists. The DWFPs ultimate objectives are to develop integrated vector control systems, find industry partners to bring novel products to the public health market, and make them available for military use. This article highlights DWFP program accomplishments achieved through its competitive grants process, exemplified by the rodent feed-through technique with insecticidal baits for controlling phlebotomine sand flies; developing attractive targeted sugar bait for use against mosquitoes and sand flies; developing a lethal oviposition trap for container-breeding mosquitoes and evaluating using pyriproxyfen (an insect growth regulator) and autodissemination by these mosquitoes to block their reproduction and metamorphosis; defining the limitations of insect repellents against infected vectors; and developing the Florida Fly Baiter and several types of novel sprayer equipment for insecticide application.

**Key Words:** Armed Forces Pest Management Board (AFPMB); Deployed Warfighter Protection (DWFP); insecticides, integrated vector control (IVC); military entomology

Now in its 10th year, the Deployed Warfighter Protection (DWFP) research program of the United States Department of Defense (DoD) is an initiative to develop, validate, and use novel products and integrated vector control systems to protect deployed U.S. military forces from threats posed by vector-borne diseases. The DWFP was initiated to focus on these disease threats for two reasons. First, these diseases have historically been the most important nonbattle health risks facing deployed troops (Dickens 1990, Peterson 1995, Withers and Craig 2003, Coleman et al. 2006, Aronson 2008). Even during the last 10 years, vector-borne diseases have impacted military operations, with 916 cases of malaria (Armed Forces Health Surveillance Center [AFHSC] 2011a), 2,549 cases of leishmaniasis (AFHSC 2011b), 930 cases of dengue (AFHSC 2011c), and 349 cases of arthropod-borne hemorrhagic fevers (AFHSC 2011d) reported in U.S. military service members and military health system beneficiaries (i.e., military family members, retirees, etc.). Secondly, the variable efficacy of insecticides on different species of blood-sucking arthropods, rising problems of insecticide resistance and a diminishing number of safe, cost-effective pesticides available for control of disease vectors and other public health pests have limited the options available for protecting deployed forces (Zaim and Guillet 2002, Kelly–Hope et al. 2008, Rowland and N’Guessan 2009). For these reasons, the DWFP research program has boosted support for discovering and developing better tools for vector control and personal protection to reduce the risk of vector-borne disease transmission.

**Administration and Areas of Emphasis of the Program.** The DWFP is managed by a military Research Liaison Officer assigned to the Armed Forces Pest Management Board (AFPMB). The program began in 2004 with US\$5 million per year being allocated between a noncompetitive funding process for research performed by the U.S.

Department of Agriculture–Agricultural Research Service (USDA–ARS) and a competitive grants process open to non-USDA–ARS scientists, with national and international investigators from academia, industry, and governmental agencies, including the DoD. The DWFP research portfolio emphasizes three areas of research: novel insecticide chemistries or formulations, application technologies, and personal protective measures. The first focus area includes discovering new active ingredients or using existing chemistries or formulations in new ways against pests and vectors of public health importance. The second includes developing novel technologies and integrated strategies to control arthropods of public health importance, while the third area is focused on developing new personal protection methods, including topical repellents, spatial repellents and treated textiles. To date, most of the research has focused on chemistries, technologies, and repellents to control mosquitoes, phlebotomine sand flies, and filth flies. A comprehensive listing of published research supported by DWFP funds for both USDA–ARS and competitive grant recipients is available on the AFPMB Web site at <http://www.afpmb.org/pubs/dwfp/publications.htm>.

To support research on innovative products and methods for vector control and personal protection, DWFP provides ~US\$3 million per year to the USDA–ARS National Program for Veterinary, Medical and Urban Entomology. These funds are currently distributed to six USDA laboratories: the Center for Medical, Agricultural, and Veterinary Entomology (CMAVE), Gainesville, FL; the Invasive Insect Biocontrol and Behavior Laboratory (IIBBL), Beltsville, MD; the Natural Products Utilization Research Unit (NPURU), Oxford, MS; the Areawide Pest Management Research Unit (APMRU), College Station, TX; the Knippling–Bushland U.S. Livestock Insects Research Laboratory (KBUSLIRL), Kerrville, TX; and the European Biological

Report Documentation Page		Form Approved OMB No. 0704-0188
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.		
1. REPORT DATE <b>2013</b>	2. REPORT TYPE	3. DATES COVERED <b>00-00-2013 to 00-00-2013</b>
4. TITLE AND SUBTITLE <b>The Deployed Warfighter Protection (DWFP) Research Program: Developing New Public Health Pesticides, Application Technologies, and Repellent Systems</b>		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER	
	5e. TASK NUMBER	
	5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Armed Forces Pest Management Board, 2460 Linden Lane, Bldg. 172, Silver Spring, MD, 20910</b>		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT <b>The Research Program for Deployed Warfighter Protection (DWFP) against disease-carrying insects is an initiative by the United States Department of Defense to develop, validate and use novel materials and technologies to protect deployed military personnel from vector-borne diseases, especially those transmitted by mosquitoes and sand flies. Launched in 2004 and administered by the U.S. Armed Forces Pest Management Board, the program is funded at US\$5 million annually. The DWFP research portfolio is concentrated in three areas: novel insecticide chemistries/formulations, application technologies, and personal protective measures. The program supports research by the U.S. Department of Agriculture, Agricultural Research Service National Program for Veterinary Medical and Urban Entomology, plus a competitive grants process open to non-USDA scientists. The DWFPs ultimate objectives are to develop integrated vector control systems, find industry partners to bring novel products to the public health market, and make them available for military use. This article highlights DWFP program accomplishments achieved through its competitive grants process exemplified by the rodent feed-through technique with insecticidal baits for controlling phlebotomine sand flies; developing attractive targeted sugar bait for use against mosquitoes and sand flies; developing a lethal oviposition trap for container-breeding mosquitoes and evaluating using pyriproxyfen (an insect growth regulator) and autodissemination by these mosquitoes to block their reproduction and metamorphosis; defining the limitations of insect repellents against infected vectors; and developing the Florida Fly Baiter and several types of novel sprayer equipment for insecticide application.</b>		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>7</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

Control Laboratory (EBCL), Thessaloniki, Greece. Other collaborators receiving DWFP funding through the USDA-ARS include the U.S. Navy Entomology Center of Excellence (NECE), Jacksonville, FL; the Emerging Pathogens Institute at the University of Florida, Gainesville, FL; and the USDA Inter-Regional Project #4 (IR-4) based at Rutgers University, New Brunswick, NJ. This last group is a cooperative program funded by USDA and the State Agricultural Experiment Stations (Malamud-Roam et al., 2010) to facilitate Environmental Protection Agency (EPA) registration of minor use pesticides including public health pesticides. The DWFP noncompetitive process was established because the DoD has a critical need for the multi-disciplinary research that USDA is uniquely able to provide by applying agricultural expertise to public health problems. It is also the intent of the DoD, through the DWFP program, to enhance a historically important (Sullivan 1971, Kitchen et al. 2009) and mutually beneficial collaboration with the USDA-ARS. Reviews of DWFP-supported USDA-ARS research efforts have been published by Linthicum et al. (2007, 2008), Cope et al. (2008), Hoel et al. (2010), Avant (2012), and Strickman (2012). This article highlights the accomplishments of some recent DWFP competitive grants (i.e., non-USDA efforts).

For the competitive process, the AFPMB annually releases a Broad Agency Announcement for preproposals for maximum awarding of US\$250,000 per year for up to 3 years. These preproposals are reviewed by a technical committee consisting of military and civilian subject matter experts in the Army, Navy, Air Force, and USDA-ARS. Based on the reviews, investigators may be asked to submit a full grant proposal. During the first 10 years of the program's existence, DWFP has received an average of 33 preproposals per-year from universities, DoD laboratories, private industry, and other organizations around the world. More than one-third of these preproposals have resulted in requests for full proposals, and about half of those full proposals were awarded funding. In total, 65 grants (<http://www.afpmb.org/content/deployed-war-fighter-protection-dwfp-program-overview-0>) were awarded during 2004–2013 (shown at [http://www.afpmb.org/sites/default/files/pubs/dwfp/DWFP\\_Grant\\_List\\_FY2004-FY2013.pdf](http://www.afpmb.org/sites/default/files/pubs/dwfp/DWFP_Grant_List_FY2004-FY2013.pdf)). Among the competitive grants, 40% were to universities, 32% to private industry, and 23% to various U.S. military research laboratories including the Walter Reed Army Institute of Research (WRAIR), Silver Spring, MD; the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID), Frederick, MD; the U.S. Army Medical Research Unit-Kenya (USAMRU-Kenya), Nairobi, Kenya; the Armed Forces Research Institute of Medical Sciences (AFRIMS), Bangkok, Thailand; the U.S. Naval Medical Research Unit No. 3 (NAMRU-3), Cairo, Egypt; and the U.S. Naval Medical Research Unit No. 6 (NAMRU-6), Lima, Peru. The remaining 5% of the DWFP grants have been awarded to other Federal agencies such as the Centers for Disease Control and Prevention (CDC) and foreign government agencies such as the Australian Army and Israeli Ministry of Health. The DWFP research portfolio contains a variety of potential products and techniques with many having wider applications for civilian global public health and veterinary pest control. Awardees are encouraged to seek patents and find commercial partners for their products. In this way, products can more easily be brought into the military supply system and made available to deployed forces.

**Development of a Feed-Through Technique (FTT) for Phlebotomine Sand Fly Control.** The Department of Entomology at Louisiana State University (LSU), Baton Rouge, LA, is one of two DWFP grant recipients investigating the use of FTTs to target adult and larval phlebotomine sand flies for the control of zoonotic cutaneous leishmaniasis (ZCL) in the Middle East. The goal of this research is to evaluate novel sand fly control procedures based on feeding rodents insecticide-treated systemic baits. Sand fly larvae are killed when they feed on the insecticide-laced rodent feces and adult sand flies are killed when they feed on the rodents (Fig. 1).



**Fig. 1.** Field trials showing a wild jird (*Meriones* sp.) feeding on insecticidal bait for demonstration of the feed through technique as a potential integrated method for sand fly control. Photo: Tom Mascari.

This effort initially focused on laboratory studies (Mascari et al. 2007, 2008; Mascari and Foil 2010). Later studies, in conjunction with USAMRU-Kenya, further demonstrated the effectiveness of FTT using various insecticides for larval and/or adult sand fly control (Mascari et al. 2011). Additional studies using a fluorescent tracer dye showed larvae of *Phlebotomus dubosqi* (Neveu-Lemaire), the vector of Afrotropical ZCL, did not feed on feces of the local burrowing rodents, so this intervention would not be useful as a larval control technique against that species. However, the results did show that *P. dubosqi* took bloodmeals from target reservoir rodents indicating the FTT could still potentially be used as part of an integrated control program against adult sand flies. Ongoing work is focusing on larger field trials and further assessment on the viability of FTT as a sand fly control technique.

In the other DWFP funded to develop the FTT (Borchert et al. 2009) for control of sand flies, Genesis Laboratories, Inc., Wellington, CO, using different active ingredients demonstrated effectiveness in the laboratory and developed insecticidal baits for burrowing rodents such as the fat sand rat (*Psammomys obesus* Cretzschmar) and various jirds (*Meriones* spp.) that serve as reservoirs for ZCL in the Middle East (Poché 2010). Wasserberg et al. (2011) built on this work by showing imidacloprid was effective against both larval and adult *P. argentipes* Annandale and Burnetti in Israel. Laboratory and field studies in Tunisia (Derbali et al. 2012) and India (Ingenloff et al. 2012) showed significant levels of control as a systemic sand fly larvicide and adulticide.

Based on those successes, Genesis Laboratories worked with Scimetrics Ltd., Wellington, CO, and their EPA registered 'Kaput Rodent Flea Control Bait' (RFCB), an imidacloprid-based product used for controlling vectors of plague (i.e., fleas) on rodents in the western United States. Scimetrics recently obtained EPA approval of an expanded use label for Kaput to be used for the FTT against medically important sand flies associated with rodent reservoirs of leishmaniasis. That EPA decision represents two regulatory "firsts" accomplished by the DWFP: acceptance of foreign efficacy data and inclusion of non-American vector species on a U.S. registered insecticidal product. Another company is currently developing an equivalent RFCB product based on an insect growth regulator (chitin synthetase inhibitor) for controlling phlebotomine sandflies and fleas. In summary, these DWFP-funded FTT projects resulted in EPA registrations of commercial products that have improved the integrated control of sand flies





**Fig. 2.** Field application of attractive targeted sugar bait for adult phlebotomine sand fly control in Israel. Photo: Gunter Müller.

for the military as well as civilian communities in regions endemic for leishmaniasis.

**Development of Attractive Targeted Sugar Baits (ATSBs) for Sand Fly Control.** Israeli researchers have been working for some time to develop effective ATSBs for control of sand flies and mosquitoes (Müller et al. 2008, 2010a, 2010b; Schlein and Müller 2010; Müller and Schlein 2011). The DWFP has helped accelerate this work by awarding several grants targeted at controlling sand flies. The DWFP goal is to develop suitable formulations, dispensers and/or ATSB barriers for use around military installations, training and housing areas to protect individuals against biting flies. Müller and Schlein (2011) with DWFP-funded Westham Innovations, Tel Aviv, demonstrated ATSB efficacy using boric acid solutions against sand flies when applied as a barrier on vegetation, low fences, or bait stations (Fig. 2). These field experiments showed that ATSBs provide significant reductions of sand fly populations in treated areas.

Other DWFP-funded efforts from Westham Innovations using ATSBs include 1) evaluating other formulations and active ingredients; 2) measuring attraction distance of different carriers such as bait stations or pellets soaked or coated with ATSBs; 3) evaluating the effect of dust and dirt burdens on the efficacy of ATSBs; 4) determining suitable time intervals in which ATSBs should be reapplied; 5) improving bait formulations to completely dry components so that water only needs to be added just before use; 6) improving bait station function and use of hollow pellets in dusty areas; and 7) evaluating the impact of ATSBs on nontarget organisms, particularly pollinators, in the laboratory and field.

In addition, the Israeli Ministry of Health in collaboration with the WRAIR was funded to examine ATSB efficacy using different active ingredients. Early results found several effective insecticide active ingredients but they needed additional field evaluations (Orshan et al. 2011). Complementary laboratory work by Allan (2011) with mosquitoes and by Foil and Mascari (2010) with *P. papatasi* sand flies found several promising active ingredients for use in ATSBs. Hence, ATSBs with different active ingredients are being developed for EPA registration and commercialization. This technique is also receiving interest from the World Health Organization and the Bill and Melinda Gates Foundation for controlling mosquito vectors of malaria and dengue.

**Development of Pyriproxyfen-Based Autodissemination for Controlling Container-Breeding Mosquitoes.** DWFP-funded projects have supported investigations into using pyriproxyfen, a powerful insect growth regulator, against *Aedes aegypti* (L.) and *Ae. albopictus* Skuse. The first project was in a Peruvian Amazon community in Iquitos, where *Ae. aegypti* transmits multiple serotypes of the dengue virus. Researchers from NAMRU-6, Peru, with local collaborators and colleagues from the University of California, Davis and Rothamsted Research, United Kingdom (Sihuinchu et al. 2005, Devine et al. 2009), demonstrated autodissemination as a control method initially proposed by Itoh et al. (1994). The principle of autodissemination is that an insecticide (e.g., pyriproxyfen) is broadcast in the mosquito's habitat where it is picked up and carried by female mosquitoes from their resting sites to oviposition sites. The females then deposit sufficient toxicant to the water resulting in inhibition of mosquito larval development. This technique would be especially important for mosquitoes that use cryptic breeding sites that are often not easy to locate and treat. Building on the pyriproxyfen results from Peru, military entomologists at AFRIMS, Bangkok, evaluated the autodissemination technique against *Ae. aegypti* in Thailand, but reported mixed results (Evans et al. 2009).

Collaborators at the Rutgers University Center for Vector Biology (CVB), New Brunswick, NJ, and local collaborators received a DWFP grant to evaluate pyriproxyfen treatments in urban New Jersey using backpack sprayers and ultra-low-volume (ULV) applications. These DWFP funded pyriproxyfen trials supplemented a USDA–ARS funded Area-Wide Pest Management Program for the Asian Tiger Mosquito (USDA–ARS 2008). As part of the grant, the NECE in Florida is conducting parallel experiments to replicate the CVBs pyriproxyfen studies in a more subtropical environment.

Results to date indicate some evidence of autodissemination where evenly distributed applications were made to 5% of the homes throughout several urban residential areas in Mercer and Monmouth Counties, NJ. Concurrently, more promising results were seen for applications made to tire piles that were monitored for autodissemination and dispersal of pyriproxyfen in concentric rings radiating out from the central treatment site (R. Gaugler, personal communication). The work also resulted in the design and patent submission of an autodissemination station (Fig. 3) that incorporates pyriproxyfen (Gaugler et al. 2012) and is designed to make use of “skip oviposition” behavior where gravid female container breeding mosquitoes oviposit at multiple locations. Pyriproxyfen field trials under an expanded EPA experimental use permit were conducted in 2011 in New Jersey and Florida (Gaugler 2011).

**Development of a Lethal Ovitrap (LOT) for Dengue Vector Control.** Dengue has been introduced periodically in the United States since colonial times. Most recently, an historic outbreak occurred in 2009 in Key West, FL, with nearly 100 cases (Florida 2010, CDC 2010). This reappearance of dengue in the United States provided an opportunity to conduct field evaluations of the U.S. Army's patented LOT for dengue vectors (Perich and Zeichner 1999, 2001, 2002). The LOT was licensed to SpringStar Incorporated, Woodinville, WA, for commercial production and worldwide marketing. After initial laboratory testing, the LOT was evaluated in Brazil (Perich et al. 1999), Thailand (Sithiprasasna et al. 2003), and Australia (Ritchie et al. 2009) with inconsistent results. The prototype SpringStar LOT (Fig. 4) used bifenthrin treated paper strips for killing eggs, larvae, and female mosquitoes when they alight to oviposit. In July 2010, in collaboration with the U.S. Army Public Health Command (USAPHC), NECE, AFPMB, and local Key West Naval Air Station volunteers, ≈7,000 LOTs were placed and mapped throughout Old Town Key West, FL. Fielded LOTs were checked every 2 weeks for the presence of mosquitoes while populations of the local dengue vector, *Ae. Aegypti*, were monitored and subjected to intensive control measures. Results were inconclusive and showed that there was a need to further refine the insecticide formulation and ovistrip in the LOT. Additional field



**Fig. 3.** Prototype pyriproxifen autodissemination station for use against *Ae. aegypti* and *Ae. albopictus*. Photo: Randy Gaugler.



**Fig. 4.** Prototype lethal ovitrap manufactured by Springstar Inc. Photo: Mike Banfield.

trials are planned to evaluate the LOTs using different active ingredients and against other field populations of *Ae. albopictus*. In January 2011, the WRAIR and USAPHC, who initially developed the LOT, were selected as winners of the Federal Laboratory Consortium 2011 Award for Excellence in Technology Transfer for this novel way to kill container breeding mosquitoes.

**Development of Filth Fly “Attract and Kill” Products.** Filth breeding flies are ubiquitous pests and potential disease vectors during military deployments (AFPMB 2011). Available filth fly control measures such as baited traps, UV light sources, space and residual sprays all have limitations and none provide 100% control when used alone

(AFPMB 2011). DWFP-funded work at the University of Florida Urban Entomology Laboratory helped facilitate the registration of an imidacloprid-based insecticide (Maxforce Fly Spot Bait) that is now readily available to the military and public.

Through the DWFP, the University of Florida developed an additional filth fly control device initially called the fly attractant system with toxicant treated cords (FAST-TC). Promising laboratory and field tests (DiClaro et al. 2009, Koehler et al. 2010, DeFranco 2010), were followed by licensing and commercialization of the Florida Fly Baiter (FFB) in 2011 by the Killgerm Corporation, Ossett, West Yorkshire, United Kingdom (Fig. 5). The FFB was designed based on detailed housefly behavioral tests, including electroretinograms, which identified the best shade of blue and shape of vertical black elements (DiClaro et al. 2012). The result is a triangular device made from flexible blue plastic with vertical black cords sprayed with Maxforce Fly Spot Bait. Flies attracted to the trap feed on the bait and are killed. Preliminary trials at the USDA–ARS European Biological Control Laboratory in Thessaloniki, Greece, showed that the traps can form an effective barrier between fly sources (cattle barns) and human quarters (A. Chaskopoulou, personal communication). Other relevant DWFP filth fly research includes work by Geden (2005, 2006), Geden et al. (2009), Chaskopoulou et al. (2009), Mann et al. (2010), and Turell et al. (2010).

**Vector Control Spray Equipment Development.** A small engineering company, Dorendorf Advanced Technologies LLC (DAT), Winnebago, MN, was awarded several DWFP grants which generated three patents (Dorendorf 2004, 2006, 2009) and two patents pending. As a result, this company developed a diesel-powered ULV truck-mounted sprayer (i.e., the Terminator) and a compressed air-powered backpack sprayer called the QJSX. The latter is unique in that it silently delivers a constant flow rate and produces uniform droplet spectra for residual applications (Fig. 6). The Terminator machine has a built-in air compressor that can also be used to charge air cylinders that power the silent QJSX. Additionally, the Terminator has a unique high pressure nozzle that improves droplet spectra for ULV applications. Both of these sprayers are now commercially available and the Terminator ULV machine is now a standard equipment item used by U.S. Navy entomologists when they deploy overseas.

More recently, and in conjunction with the annual NECE “Equipment Rodeo” where various pesticide spray equipment manufacturers simultaneously characterize their sprayers (Hoffmann et al. 2007, 2008), DAT tested a prototype high-performance ULV backpack



**Fig. 5.** Florida Fly Baiter filth fly control device ([http://www.pestwest.com/us/florida\\_fly\\_baiter.php](http://www.pestwest.com/us/florida_fly_baiter.php)). Photo: D Burkett.





**Fig. 6.** Compressed air-powered backpack sprayer (JQX) that silently delivers a constant flow rate and consistent droplet spectra. Photo: Bruce Dorendorf.

sprayer called the U-BLAS-ONE (Fig. 7). The U-BLAS-ONE sprayer contains a patented DAT nozzle that produces droplet spectra comparable to the best performing truck-mounted ULV machines (Walker 2010). Under another DWFP grant, DAT is developing another machine that possesses the best properties of both ULV and thermal fog sprayers. This unit also has the potential to improve insecticide efficacy for vector control operations. The DATs innovative products epitomize the purpose of the DWFP program: Provide cost-effective, battlefield-ready integrated vector control spray equipment for use by deployed warfighters at a reasonable cost that also have applicability in the civilian public health sector.

**Topical Repellent Efficacy Against Mosquitoes and Sand Flies Infected with Human Pathogens.** The WRAIR has had several DWFP grants applied to sand fly related projects including detection, pathogen identification, and control evaluations in Iraq (Coleman et al. 2009); establishment and maintenance of phlebotomine sand fly colonies (Rowton et al. 2008); and evaluations of commercial metafluthrin-based emanators for sand fly control (Zollner and Orshan 2011). Additionally, topical repellents and permethrin treated uniforms are an integral part of the personal protection system advocated by the U.S. military against biting and potential pathogen carrying arthropods



**Fig. 7.** Prototype ULV backpack sprayer (U-BLAS-ONE) built by DAT and evaluated during annual “equipment rodeo” conducted by the Navy Entomology Center for Excellence (NECE). Photo: Todd Walker.

(AFPMB 2009). The possibility of diminished arthropod repellency to these uniforms after they have become infected with human pathogens could be important for military operations and global public health objectives. Indeed, preliminary data from USAMRIID and WRAIR (E.D. Rowton, personal communication) show that, for some virus-vector combinations, infected mosquitoes were more likely than uninfected siblings to feed on DEET treated hamsters. Other recent published reports show similar findings for dengue (Frances et al. 2011) and sindbis virus (Qualls et al. 2011) infected mosquitoes. This has also been reported in sand flies where sand flies infected with *Leishmania* have different feeding patterns than those not infected (Beach et al. 1985, Svobodova and Votypka 2003, Rogers and Bates 2007). The most recent WRAIR grant is now investigating whether pathogen-infected mosquitoes (dengue, Rift Valley fever, and chikungunya) and sand flies (leishmaniasis) are less sensitive to permethrin treated military uniforms and commercially available repellents such as DEET, IR3535, and picaridin. As new repellents or repellent and insecticide combinations are developed, there will need to be additional investigation in this area. The apparent reduction in repellent effectiveness observed in the above examples also reinforces the need to develop an integrated approach to repellent use and arthropod bite protection.

We conclude that success of the DWFP research program has been largely because of collaborator synergy in both the competitive and USDA-ARS portions of the program. This diverse project portfolio includes techniques and equipment for killing disease vectors, new insecticide chemistries, and development of various types of repellents. Successful additions, now available to the military through the supply system and the civilian public health community include the Florida Fly Baiter filth fly control device, Maxforce Fly Spot Bait, additional mosquito adulticides, several insecticide sprayers, improved pesticide spray equipment based on results from DWFP sponsored efficacy trials, and changes in standard military vector control practices based on applied research conducted under the DWFP. Additionally, there are many promising DWFP-generated products that are moving toward commercialization and use by the U.S. military and civilian public health agencies. These include traditional and pyriproxyfen-based LOTs; spatial repellents for military uniforms and civilian clothing; ATSB stations and barrier applications for vector control; molecular pesticides; rodent feed through insecticides for sand fly control; new insecticide synergists, pesticides formulated for use on impervious military textiles, advancements to application equipment, nootkatone and other natural product repellents. The examples described in this article are far from sufficient to cover all of the U.S. military’s needs. Apart from combating mosquitoes and other flies that transmit debilitating diseases, there are also many other medically important arthropods that merit our concern. However, with its limited funds the DWFP will remain focused on the most important militarily relevant disease vectors: mosquitoes, sand flies, and filth flies.

The U.S. military has historically worked with partner organizations to develop the vector control equipment and techniques it requires to protect its personnel and its allies. Continued research and development with a range of such partners remains essential. The most effective control of vectors often requires employment of multiple products and control measures for integrated vector management (WHO 2011). History shows that many of the most important vector control methods and materials were discovered and developed by collaborative efforts between the DoD and the USDA-ARS (Core et al. 2005), and then commercialized for public health benefit as well as business success. Hence, we are confident that the DWFP program, with our competitive grant collaborators and USDA-ARS scientists, will yield even more innovative products to better protect U.S. military forces and the global civilian public from vector-borne diseases.

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Received 27 October 2011; accepted 30 April 2013.